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# **Archaeological science and object biography: A Roman bronze lamp from Kavastu bog (Estonia)**

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## ***Introduction***

Imported goods have attracted scholars' attention for many years. They indicate the directions and intensities of foreign contacts as well as the concepts of value and prestige in the past. A well-known example of such networks is the occurrence of Roman imports beyond the limits of the Empire, especially in northern Europe. However, the archaeological evidence of such goods and contacts in Europe is not evenly distributed and differences between regions are considerable. While some areas, like Scandinavia and central Europe provide an abundant record of Roman imports, others such as the northern regions of the Baltics clearly lie in the periphery of the Empire. In this context a unique bronze deposit containing a Roman lamp and four bronze bars from Kavastu (Estonia) was investigated in order to address the questions of biographies, function and chronology of imported goods in periphery regions.

Igor Kopytoff's ground-breaking paper on artefact biographies (Kopytoff 1986) has influenced scholars dealing with the life history of archaeological objects and sites for decades (e.g. Bradley 1993; Holtorf 1998; 2002; Gosden & Marshall 1999; Fontijn 2002; Joy

2009). Several previous studies have also emphasised the issues of long-term use of rare, foreign and prestigious luxury items (Lillios 1999; Härke 2000; Whitley 2002; Eckhardt & Williams 2003) as well as the importance of reconstructing biographies of hoarded objects to provide more nuanced and better substantiated interpretations of those finds (Lund & Mellheim 2011; Hall 2012; Dietrich 2014). These works have widened our understanding of the processes behind creating and collecting valuables, their origins and life-cycles, problematized elaborations about the chronology of those deposits, but also multiple functions and meanings of material culture in general.

This article contributes to the discussions of biographies of import goods in periphery regions. We focus on determining the chronology and function of imported objects in foreign contexts and considering the problems of estimating the time of deposition of such items outside their provenance areas.

Several scientific methods were combined in order to create a biography for the Kavastu bronze lamp and develop a more robust interpretation for this find in the context of eastern Baltic Iron Age. We demonstrate that an analysis that purely relies on chronology and typology of imported goods omits important information that contributes to the final interpretation of the find. We also show how historically developed research traditions of interpreting such artefacts influence and might even mislead our understanding of these objects. We exemplify the relevance of multidisciplinary analysis in material culture studies, especially when dealing with rare items that have very few archaeological parallels locally.

### ***The Kavastu bronze lamp and its parallels***

The Kavastu bronze lamp was first described and published by Richard Hausmann (1905). It is a large two-nozzle bronze lamp with volute-decorations (Figure 1) weighing 1245 grams. Two fragments of possibly Roman objects (lamp-stand?) and two bronze bars were found with the lamp. By their appearance these could be considered as raw material metal bars.



Figure 1. The Kavastu bronze deposit: a Roman lamp and four bronze bars, and close-up of the analysed residue *in situ*.

The deposit was recovered during peat cutting around four feet deep at the bank of River Emajõgi in Kavastu (Kawwast) (Figure 2), southern Estonia in 1902 (Hausmann 1905). According to the initial description of the discovery there were several animal bones in the area, although it is specifically reported that recognisable human bones, like skulls or long bones, were not noticed.



Figure 2. The 19<sup>th</sup> century map of Kavastu (ЕАА1384-1-12-1. Планъ имения Кавастъ, map from the Estonian National Archives) on an Estonian Land Board relief map with a contemporary peat cutting area (*торф ями* in Russian) marked in red.

Similar voluted two-nozzle bronze lamps have been recovered from Pompeii and Herculaneum (Valenza 1977: 159, table LXXII: 8; Conticello de' Spagnolis & De Carolis 1988: 41–45, table 3) including in and around the destruction layer of 70–79 AD. Parallels are also known from the Mahdia shipwreck from the first century BC discovered in the waters of Tunisia (Fuchs 1963: 30, table 43–44; Parker 1992: nos. 621, 252). These examples are mostly with a handle, sometimes also with a short stand attached to the bottom of the lamp.

According to Conticello de' Spagnolis and De Carolis (1983: 16–17; 1988: 41) such lamps were in use in the Roman Empire at least until the second century AD. However, bronze lamps in general were luxury items, even in the Roman Empire, where clay lamps were mainly used. Bronze exemplars were rare, expensive, used in special occasions and for much longer periods of time, especially in the north of the Alps (Goethert & Werner 1997: 182). Two very similar two-nozzle, though slightly smaller, Roman bronze lamps are known in central Europe, in Moravia (Czech Republic): a stray find at Bílovice near Kostelec, and as a burial inventory in the princely grave at Mušov (Schránil 1928: 268, table LV: 18; Droberjar 2002: 114–115, 192; Tejral 2004: 339). Besides the Kavastu lamp, no other Roman bronze lamps have been found either in Scandinavia or in Baltic countries.

### ***Roman import in northern Europe***

Roman import in northern Europe is not a rare phenomenon. Scandinavia, especially its southern regions have abundant material of both Imperial and provincial Roman goods, from jewellery to coins and glass or metal vessels (Eggers 1951; Lund Hansen 1987). There is no doubt that those regions were in contact with the Romans directly and indirectly. This is also indicated by written sources and the inventory of Roman goods in famous Scandinavian booty sacrifices (Ilkjær 2000; Jørgensen *et al.* 2003). The movement of import goods might have been rather rapid within and into these regions although the prolonged use of some prestigious objects is likely.

The situation is somewhat different in the eastern Baltic. Poland and Lithuania are in the spotlight of the Roman Empire, arising not only from the amber trade but also due to their geographical closeness to Roman activities (Bursche 1992; Michelbertas 2001; Bliujienė 2011; Zapolska 2012). Thousands of coins and other Roman and provincial goods have been found in those regions. However, the number of imports decreases drastically towards the north. Around 500 Roman coins have been found in Latvia with only four certain coin hoards (Ginters 1936; Urtāns 1977: 133–137; Ducmane & Ozoliņa 2009). In Estonia the majority of import items are gold foil and glass beads (Lang 2007: 257), whilst there are very few sites with Roman bronze goods (see Figure 6 below). Around 100 Roman coins have been discovered in Estonia, with only three certain coin hoards (Kiudsoo 2013). In Finland, the number of Roman goods is even smaller, with some 20 coin finds and three bronze drinking

vessels (Eggers 1951: 158, nos. 2256–2258; Kivikoski 1961: 117; Talvio 1982; Salo 1984: 218–219).

In this context, the discovery of a Roman bronze lamp in Estonia is remarkable. The closest find in a functional sense would be a simple single-nozzle clay lamp from Kapseda in Latvia (Ginters 1936; Moora 1938: 586–587, fig. 86). Other than these two there are no prehistoric oil lamps in the eastern Baltic archaeological material, except Stone Age shallow ceramic bowls, the so-called blubber lamps. Thus, the Kavastu bronze lamp is a unique find in terms of form and function in its spatial and temporal context: it is the only such find in the Baltic Sea area and the largest single Roman bronze object in the north-east Baltic.

### ***The existing biography for the Kavastu lamp***

Reconstructing the biography of the Kavastu lamp starts by defining its date and place of ‘birth’. Similar lamps from Roman Empire were made and used from the late first century BC to the second century AD. Taking that as a possible *tpq* for the Kavastu deposit, the concealment of the lamp might have taken place after the first–second century AD. However, such a direct estimation would dismiss several problematic issues such as long-distance trade networks and long-term (re-)use of objects. In the case of vast geographical and cultural distances, correlating the time of production of an object and its deposition in the final destination is problematic.

Hausmann discusses the origin and the chronology of the lamp in his article from 1905. In consultation with Prof. Adolf Furtwängler from Munich, he identifies the lamp as an imperial product, made in what-is-now Italy in the first century AD (1905: 65). He also organised chemical analysis of the metal content of the lamp and three bars concluding that all these items must have been from different artefacts, because the content of alloys varies considerably (Table 1). Leading on from those analyses, Hausmann points out the problems with the chronology of the deposit. He argues that the alloy contents of bronze bars, especially the high content of lead, and comparative local material from the second half of the first millennium AD, show that some of them might belong to a much later period, even around the turn of the first and second millennium AD (Hausmann 1905: 68–73).



Table 1. Alloy content of artefacts in the Kavastu deposit (after Hausmann 1905: 68–69).

Artefact	Cu (%)	Sn (%)	Pb (%)	Zn (%)	Fe (%)	Total (%)
Lamp	86.22	11.56	0.59	0	1.02	99.39
Fragment no. 2	67.78	6.31	25.21	0	0.40	99.70
Fragment no. 4	66.30	1.93	9.01	21.41	0.71	99.36
Fragment no. 5	74.24	4.35	20.03	0	0.81	99.43

Despite Hausmann's conclusions, the find still became discussed in the context of Roman Iron Age (50–450 AD) in all the following archaeological publications (Moora *et al.* 1936: 93; Jaanits *et al.* 1982: fig. 159; Lang 2007: 257). The lamp was regarded as an example of a Roman import and the manifestation of foreign contacts with the northern periphery during Roman Iron Age. This exemplifies a slightly superficial nature of the scholarship that substantiated their conclusions on the artefact based chronology of the lamp, without going into details of what has been proposed by Hausmann about the date of the deposit.

The Kavastu deposit was taken into a fresh research focus in 2012 in relation to a PhD project on eastern Baltic first to ninth century AD wealth deposits (intentional artefact concealments) (Oras 2015). At the time of deposit discovery in 1902 Estonian territory was part of Tsarist Russian Empire. Despite being discovered in Estonia the find was sent to the archaeological collections in Riga Dome Museum in Latvia after initial study. Later it was handed over to the National History Museum in Latvia where it is stored now. We have not found detailed records about cleaning, conservation and storage procedures, or display of the lamp throughout these past hundred years. However, during the first inspection of the find it became evident that some of the fuel residue was still left intact in the lamp nozzle. This provided an opportunity to obtain new insights into the life-cycle of the lamp and its relationship with the bronze bars, through characterising and dating the residue in the lamp. Several questions relating to the origin, use and deposition of the lamp emerged: when and where was the lamp last used for lighting purposes? What is the residue used as a fuel and is it of northern origin? What is the date of the deposition and does it coincide with the artefact chronology of such lamps? Does the direct dating of the fuel correlate with Hausmann's estimation based on metallurgical analysis?



## ***Further scientific analysis: The biography improved***

### **Residue analysis**

To estimate the possible region(s) where the lamp had been used, the first step was to determine the fuel residue in it.

A detailed analytical protocol of the fuel residue analysis is presented in Supplementary Online Material. A partial gas chromatogram showing the results is presented in Figure 3. The sample is characterised by a narrow monomodal distribution of *n*-alkanoic acids ranging from C<sub>12</sub> to C<sub>22</sub> in carbon number with an even-over-odd preference dominated by an *n*-C<sub>16</sub> homologue. Several monounsaturated C<sub>18</sub> *n*-alkanoic acids are also present at a relatively high concentration, and C<sub>7</sub>–C<sub>9</sub> diacids are also observed, with the C<sub>9</sub> diacid (azelaic acid) present at the highest concentration. The *threo*- and *erythro*-stereoisomers of 9,10-dihydroxyoctadecanoic acid elute at 26.0 and 26.4 min, respectively. A trace concentration of 24-ethylcholest-5-en-3 $\beta$ -ol ( $\beta$ -sitosterol) was present (not shown), however, no cholest-5-en-3 $\beta$ -ol (cholesterol) was detected. The carbon number distribution of the *n*-alkanoic acid homologues, combined with the presence of  $\beta$ -sitosterol, albeit at a trace concentration, and the absence of any detectable cholesterol may be interpreted as evidence of a higher plant origin for the lamp residue (Killops & Killops 2005). The presence of azelaic acid and 9,10-dihydroxyoctadecanoic acid may be explained as oxidation products of octadec-9-enoic acid (most likely oleic acid; Regert *et al.* 1998) indicating that this component would have been present at a much higher concentration (most likely the dominant *n*-alkanoic acid moiety) at the time of the lamp's use.

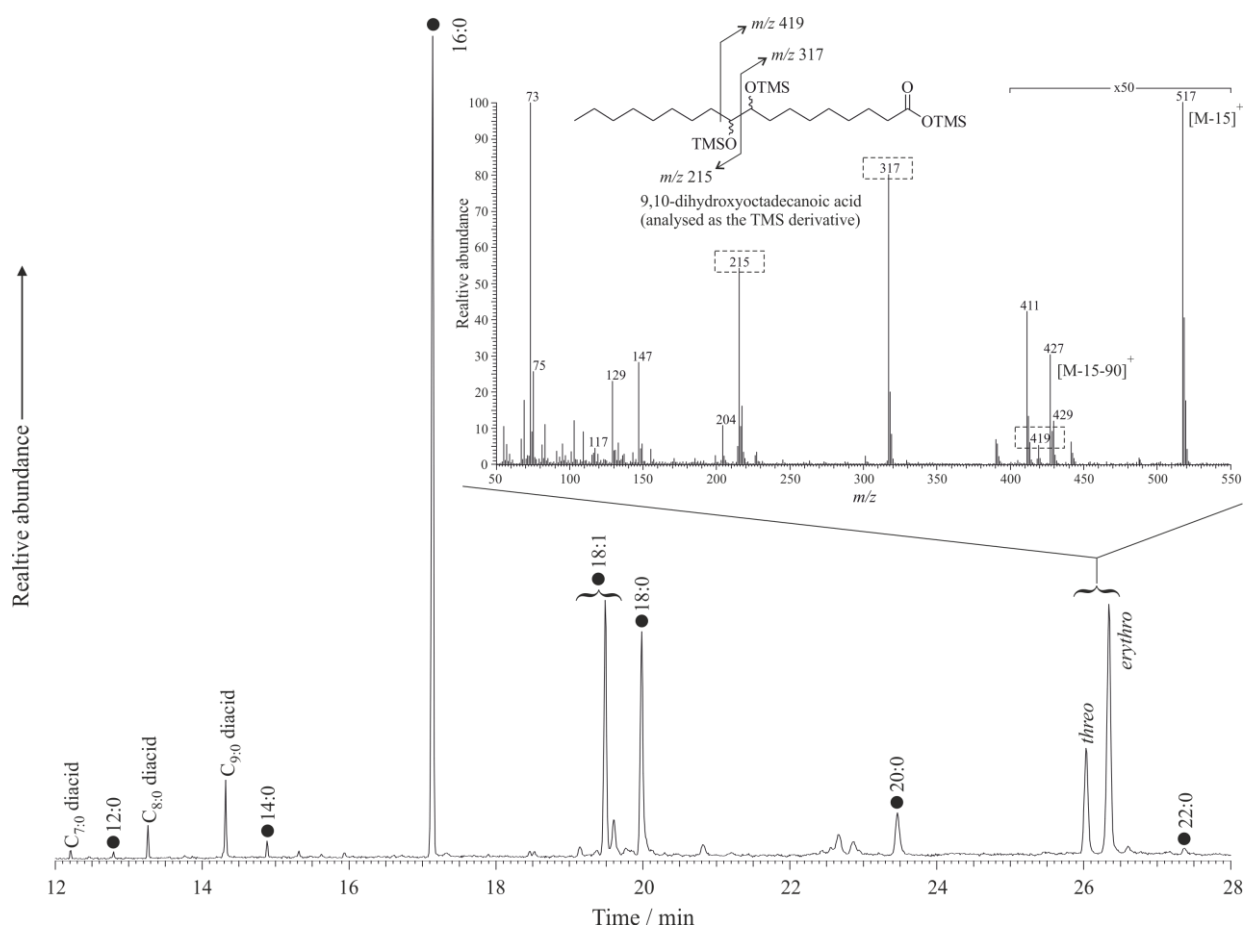


Figure 3. Partial gas chromatogram of the trimethylsilylated lipid extract from the fuel residue from Kavastu bronze lamp. Free *n*-alkanoic acids are denoted by filled circles, with *x*:*y* giving the carbon chain length *x* and degree of unsaturation *y*.

The analysis of the stable carbon isotope signature of single *n*-alkanoic acids supports the interpretation of a plant-oil derived fuel for the lamp, with values of C<sub>16:0</sub> against C<sub>18:1</sub> consistent with ranges obtained for a range of European C<sub>3</sub> oils (Figure 4; Woodbury *et al.* 1998).

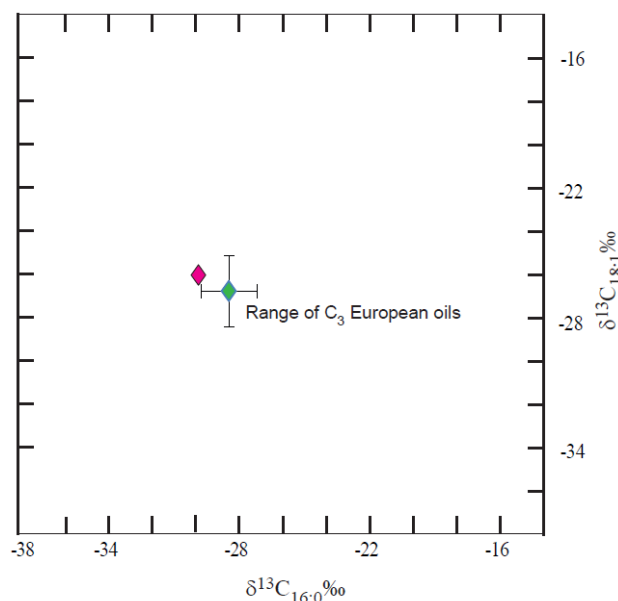


Figure 4. Plot of  $\delta^{13}\text{C}$  values of C16:0 against C18:1 *n*-alkanoic acids, showing the range of European C<sub>3</sub> oils (Woodbury *et al.* 1998) with the Kavastu results marked with red diamond.

## Radiocarbon dating

AMS dating was carried out in the Oxford Radiocarbon Accelerator Unit. There were two main aims: (i) to estimate the date of final use of the lamp and its *tpq* for the deposition, and (ii) to compare the  $^{14}\text{C}$  date of the lamp residue with the temporal estimations of the deposit based on Roman artefact typology and chronology, and metallurgical analysis presented by Hausmann. We dated two bulk samples of the carbonised residue and tested the dating of the total lipid extract (TLE) solvent extracted for the lipid residue analysis. The *in situ* residue was spatially homogeneous and removed as a single batch from one of the lamp's nozzles, later divided into two separate bulk samples. Radiocarbon determinations were obtained using the methods outlined by Brock *et al.* (2010).

The radiocarbon dates obtained for two bulk samples are presented in Figure 5, and Table 2. The first bulk AMS sample (OxA-27781) yielded a radiocarbon date of  $1561 \pm 25$  BP, which is calibrated to 427–557 AD (95.4% probability). The second bulk sample of the fuel residue (OxA-32327) provided a date of  $1699 \pm 33$  BP, calibrated to 252–410 AD (95.4% probability). A radiocarbon date determination for the TLE (OxA-V-2515-13) yielded a much earlier date of  $2319 \pm 31$  BP, cal. 430–356 BC (88.4% probability). However, this discrepant

and archaeologically-unlikely date most likely arises from the insufficient removal of organic solvents, adding infinitely old carbon to the sample (see further discussion in Supplementary Online Material). Thus, we consider the TLE age erroneous for dating the usage of lamp for illumination purposes, whilst the two bulk determinations —  $1699 \pm 33$  BP and  $1561 \pm 25$  BP — provide a *tpq* after which the lamp and the bars must have been deposited.

Table 2. Radiocarbon determinations and analytical data for the bulk Kavastu lamp residues. Yield (%) is the percent yield of pretreated material as a function of the starting weight of the material analysed. %C is the carbon present in the combusted sample. Stable isotope ratios are expressed in ‰ relative to vPDB with a mass spectrometric precision of  $\pm 0.2$ ‰.

OxA	Date	$\pm$	Used (mg)	Yield	% Yld	%C	$\delta^{13}\text{C}$ (‰)
27781	1561	25	57.96	37.46	64.6	25.4	-27.2
32327	1699	33	27.51	13.64	49.6	16.4	-26.2

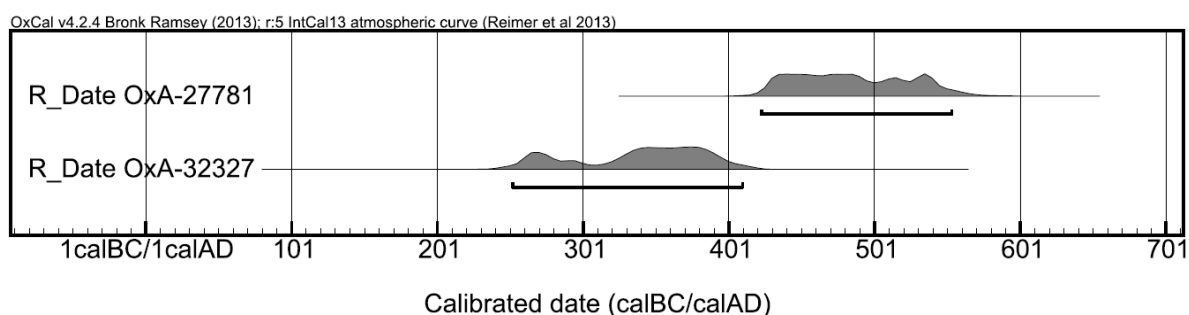


Figure 5. Calibrated age ranges for the two bulk radiocarbon determinations from the lamp (OxA-27781 and OxA-32327; see data in Table 2). Calibrated using OxCal 4.2 and the INTCAL13 calibration curve (Reimer *et al.* 2013).

### ***Discussion: A new biography for the Kavastu lamp***

The residue and AMS analyses in combination with metallurgical studies make a substantial contribution to reconstructing the biography of the Roman bronze lamp and bars discovered in Kavastu.

The lamp is a Roman production from the Mediterranean dating to around the first century BC – second century AD. The bulk AMS dates indicate that it has been used as a source of light for several centuries after its production. Due to sampling procedures we cannot be absolutely certain that the residues reflect different episodes of use separated by several centuries, but they might imply at least two later use phases for the lamp: the first around third – early fifth century AD (sample OxA-32327) and the preceding latest use around fifth – sixth century AD (OxA-27781). This would support the idea of long-term use of bronze lamps and their prestige value as sources of illumination.

The origin of the residue indicates where the lamp was used for illumination purposes. We know that in the Mediterranean mainly olive oil, potentially with other plant substances and as mixtures with animal fat (Kimpe *et al.* 2001; Colombini *et al.* 2005; Copley *et al.* 2005; Garnier *et al.* 2009; Steele *et al.* 2010), but also beeswax (Evershed *et al.* 1997) were used in lamps. In the Kavastu lamp the fuel used was of C<sub>3</sub> plant origin, most likely olive oil. The import of olive oil into north-east Europe would be possible in principle, but we lack any archaeological finds like oil amphorae or identified olive oil use in any other vessels in the archaeological record. Furthermore, considering that Roman import is generally rare (mainly glass beads and a couple of brooches, see Figure 6 below) it is unlikely that such a specific commodity like olive oil was imported and indeed used for illumination purposes in this periphery northern region. Although there are local C<sub>3</sub> oil plants e.g. flax and hemp available, we have no evidence of oil production from these plants. Their fibres were utilized in textile production and if oil was produced at all it was probably consumed as valuable food substance (Troska & Viires 1998; Moora 2007: 23–24, 188–190) making burning of such oils unreasonable.

Furthermore, the Kavastu and previously mentioned Kapseda ceramic lamp are the only oil-lamps known in the eastern Baltic Iron Age material. Based on local archaeological and ethnographic record the main sources for heat and illumination in the region were abundant wood resources. The closest comparisons to oil lamps are considerably earlier Mesolithic and Early Neolithic ‘blubber-lamps’, ceramic bowls in which aquatic substances were burnt (e.g. Heron *et al.* 2013). Similar use of aquatic resources for illumination has also been recorded in local ethnographic material (Troska 1998: 331–332). However, in the Kavastu lamp no traces of marine or mammal substances were identified. Thus, it was probably an alien commodity,

not used in its primary function in the Nordic regions and the reason why it made it so far north must be different from its initial utilization purpose.

The closest similar lamp finds are from the south-eastern corner of the Czech Republic in central Europe. One possible route through which the lamp might have travelled to the eastern Baltic is via the Vistula River which connects central Europe with the Baltic Sea. There are a few other import goods from around Vistula in Estonian Roman Iron Age material (Jaanits *et al.* 1982: 223; Lang 2007: 156). However, although a large proportion of Roman imports reached the Baltic Sea region via sea routes, the inland water routes were as important. Based on the origin of import goods, eastward connections via inland water routes became dominant in the third–fifth century AD (Michelbertas 1972: 28–21; 2001: 35, 47; Banytė-Rowell 2004: 2; Bliujenė 2011: 171–189, 195; Kiudsoo 2014). Denser connections between eastern Lithuania and Carpathian Basin in the fifth century AD have been emphasised (Bliujenė & Curta 2011). The Kavastu deposit is located in eastern Estonia at the bank of River Emajõgi, which is the largest water route in south-east Estonia. It connects to the Lake Peipus — major water route in the north-east Europe linking several larger rivers that lead towards east, south and north. Considering the location of the deposit and its historical background the lamp most likely arrived in Kavastu via eastern routes, as part of active trading networks and connections with south-eastern Europe around the mid-first millennium AD (Jaanits *et al.* 1982: 231–232; Laul 2001).

The time when the lamp arrived in Estonia can be estimated on the basis of the latest AMS date. One bulk AMS result indicates that at least one of the lamp's use phase was around the third – fifth century AD. The other date follows immediately identifying the fifth – sixth century AD as its second utilisation period. Based on these radiocarbon dates the lamp was in use (and possibly also in circulation) for several centuries in the regions where olive oil (or other similar plant oils) were exploited for illumination purposes. Since the lamp was not used for lighting in the northern regions it must have arrived in its final location sometime after the latest date i.e. no earlier than the fifth–sixth century AD. This interpretation contradicts the artefact chronology of the lamp in its initial manufacture region by several centuries providing a good example of the importance of acknowledging possible chronological deviations in the case of imported objects.

The metallurgical studies presented by Hausmann concur with the AMS date rather well. On the basis of alloy content of the bars he argued that the act of concealment was as late as Viking Age or around the turn of the millennium. Although there has been a considerable development in the metallurgical studies of Roman and early medieval copper alloys contributing to the discussions of artefact origin, technology and chronology in southern and western Europe (e.g. Craddock 1978; Dungworth 1997; Pollard *et al.* 2015), we are still lacking similar studies for the eastern Baltic material. Thus, a more up-to-date comparison for Hausmann's conclusions based on the alloy content and its relation to chronological estimation is currently missing. Our AMS results demonstrate that this estimation could be slightly earlier i.e. sometime around or after the fifth–sixth century AD. Although the radiocarbon dates do not exclude later deposition, the archaeological context and associated finds point to an earlier timeframe for the Kavastu deposit. Specifically, there is a phenomenon of concealing bronze artefacts, mainly ornaments and their fragments, as hoards in the Migration Period (450–550 AD) eastern Estonia. Most of those finds are concealed in watery contexts and close to larger water routes (Figure 6) (Oras 2010; 2015). These include the Piilsi deposit of around 50 bronze ornaments of different date and provenance found at the Piilsi River bank; the Reola deposit of brooches and bracelets found in a peat bog; and the Vagula deposit found at the bank of a lake in south-eastern Estonia containing several bronze ornaments of which only one enamelled brooch from Dnieper region was handed over to the archaeological collections. These bronze hoards indicate a widespread intentional depositional practice around the fifth–sixth century AD in eastern Estonia. No similar and widely distributed bronze concealments are found in later centuries, when most of the hoards contain either iron or silver objects instead.

The Kavastu deposit with its bronze items in watery conditions falls into the same pattern with the other eastern Estonian Migration Period bronze deposits. Since the lamp was concealed with metal bars the overall composition of the deposit, and the fact that the lamp was not actively used in northern Europe, suggest that the find can be interpreted as a collection of recyclable raw materials.



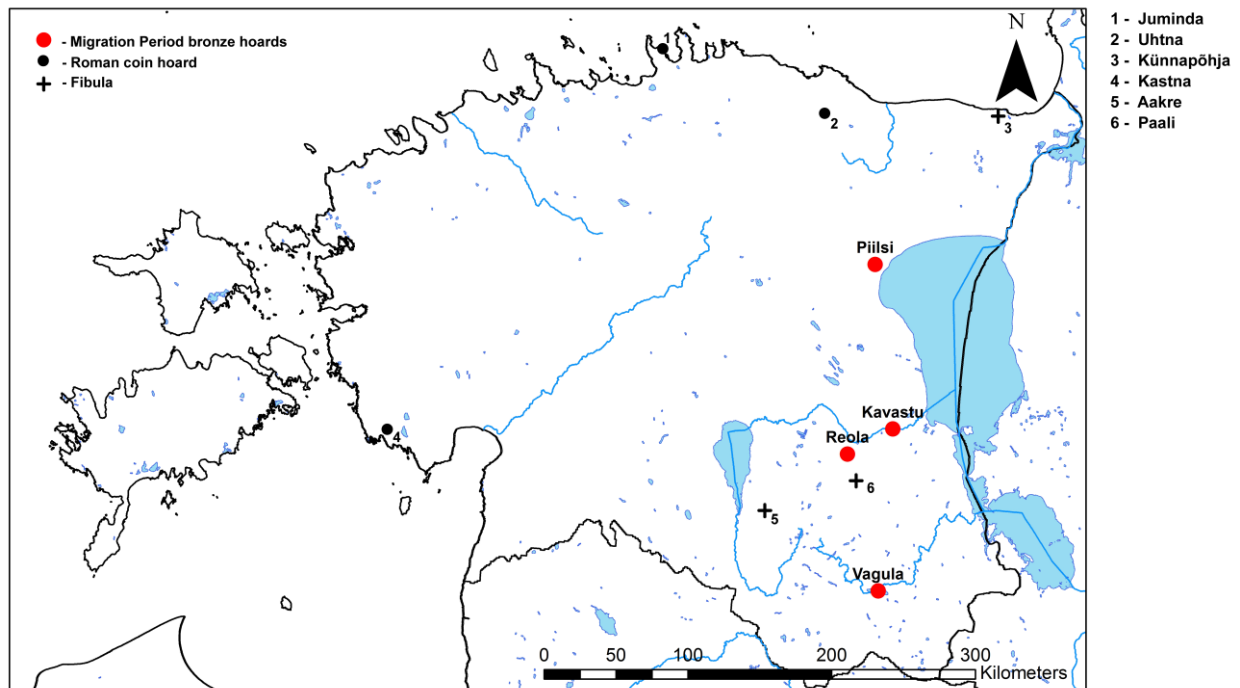


Figure 6. Map of Roman import bronze goods and Migration Period bronze hoards in Estonia.

Further interpretation of these bronze hoards and the Kavastu find in particular is complicated. They all indicate the continuous importance of bronze as the main production material for valuables — a tradition going back to the Roman Iron Age (Lang 2007). The Piilsi and the Kavastu deposits contain items that are likely meant to be re-cast in order to produce new items, probably ornaments. Laul (2001: 211–212) has argued that the local bronze manufacturing in south-eastern Estonia started to develop at the end of the Roman Iron Age. Thus the following centuries with more abundant scrap metal finds might be direct results of those local manufacturing capacities and demand for imported recyclable raw material. However, the environment of concealment somewhat contradicts with this practical reasoning. The Kavastu and the Reola finds were concealed in a peat bog whereas documentation of the discoveries note bone material recovered nearby which unfortunately did not reach museums. The Vagula deposit was found in a lake, the Piilsi at the bank of a river. The exact meaning and function related interpretations of these deposits, especially as to why water related environments were preferred, remains currently open. However, their strikingly similar content and context, geographical location and chronology argue for the importance of bronze and eastward trade routes in Migration Period eastern Baltic.

As to the biography of the lamp itself we witness shifting context-specific values and functions of one and the same object. Having been prestigious object in the Roman Empire it was used for illumination from the turn of the era to the fifth – sixth century AD. Why and how exactly the lamp ended up in northern Europe is difficult to say, but it is worth keeping in mind the turbulent times of the Migration Period and the fall of the Empire coinciding with our estimation of the lamp concealment. It might have arrived from southern or central Europe where it was still used for illumination via third parties as a useful raw material trading good appealing for the northern ‘bronze-fans’ who probably knew nothing about the use of such lamps for lighting purposes. In its new context the lamp was now conceived as important raw material concealed with other similar materials — four bronze bars. The alloy content of the latter indicates that they are parts of different artefacts: the ones identifiable as fragments of specific bronze utensils are most likely of foreign origin, whilst the others in the shape of a metal bar might be local production. This set of different origin bronze objects including a lamp, fragments of two different bronze artefacts, and possibly locally cast metal bars was now regarded as a collection of valuable metal that could be reworked into bronze ornaments perceived as prestigious items in the north. However, for some reason someone decided to hide this collection of valuables into a peat bog next to the largest water route in the area. Thanks to this decision we have been able to reconstruct the biography of a unique Roman bronze lamp from Kavastu.

## ***Conclusions***

This article discussed the questions of reconstructing artefact biography and issues of artefact chronology for imported objects on the basis of the Kavastu bronze deposit from Estonia. We have exemplified how these problems can be tackled with the help of archaeometry that enables better understanding of artefact use and chronology. Combining scientific and traditional archaeology methods we were able to reconstruct the provenance, possible travel routes, and use phases of the Kavastu bronze lamp. Its life-story stretches over half a millennium, covers thousands of kilometres from south (Roman Empire) to north (East Estonia), and encompasses variable functions from illuminating luxury item to valuable raw material.

We demonstrated how combining modern research methods with old archaeological material can make an important new contribution to our understanding of past material culture. Most importantly we illustrated how object biography can alter when further analyses are conducted, and why it is problematic, even misleading to liken object chronology and function in their original context with the items discovered at large spatial distances.

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## Figure captions

Figure 1. The Kavastu bronze deposit: a Roman lamp and four bronze bars and close-up of the analysed residue *in situ*.

Figure 2. The 19<sup>th</sup> century map of Kavastu (EAA1384-1-12-1. Планъ имения Кавастъ, map from the Estonian National Archives) on an Estonian Land Board relief map with a contemporary peat cutting area (*морф яму* in Russian) marked in red.

Figure 3. Partial gas chromatogram of the trimethylsilylated lipid extract from the fuel residue from Kavastu bronze lamp. Free *n*-alkanoic acids are denoted by filled circles, with *x*:*y* giving the carbon chain length *x* and degree of unsaturation *y*.

Figure 4. Plot of  $\delta^{13}\text{C}$  values of C16:0 against C18:1 *n*-alkanoic acids, showing the range of European C<sub>3</sub> oils (Woodbury *et al.* 1998) with the Kavastu results marked with red diamond.

Figure 5. Calibrated age ranges for the two bulk radiocarbon determinations from the lamp (OxA-27781 and OxA-32327; see data in Table 2). Calibrated using OxCal 4.2 and the INTCAL13 calibration curve (Reimer *et al.* 2013).

Figure 6. Map of Roman import bronze goods and Migration Period bronze hoards in Estonia.

## Tables

Table 1. Alloy content of artefacts in the Kavastu bronze deposit (after Hausmann 1905: 68–69).

Artefact	Cu (%)	Sn (%)	Pb (%)	Zn (%)	Fe (%)	Total (%)
Lamp	86.22	11.56	0.59	0	1.02	99.39
Fragment no. 2	67.78	6.31	25.21	0	0.40	99.70
Fragment no. 4	66.30	1.93	9.01	21.41	0.71	99.36
Fragment no. 5	74.24	4.35	20.03	0	0.81	99.43

Table 2. Radiocarbon determinations and analytical data for the bulk Kavastu lamp residues. Yield (%) is the percent yield of pretreated material as a function of the starting weight of the material analysed. %C is the carbon present in the combusted sample. Stable isotope ratios are expressed in ‰ relative to vPDB with a mass spectrometric precision of  $\pm 0.2$ ‰.

OxA	Date	$\pm$	Used (mg)	Yield	% Yld	%C	$\delta^{13}\text{C}$ (‰)
27781	1561	25	57.96	37.46	64.6	25.4	-27.2
32327	1699	33	27.51	13.64	49.6	16.4	-26.2

## Supplementary Online Material

### ***Archaeological science and object biography: A Roman bronze lamp from Kavastu bog (Estonia)***

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#### Analytical protocol for fuel residue analysis

Subsamples of the lamp fuel (1–10 g) were crushed using a pestle and mortar. The powdered deposit was ultrasonically extracted with organic solvent (chloroform/methanol, 2:1 v/v, 3 × 5 ml). Solvent was then evaporated from the combined extract under a gentle stream of nitrogen to yield a total lipid extract (TLE). An aliquot of the resulting extract was trimethylsilylated prior to analysis (30 µl *N,O*-bis(trimethylsilyl)trifluoroacetamide + 1% trimethylchlorosilane, 60°C, 1 h). The TLE obtained from the lamp deposit was analysed by gas chromatography/mass spectrometry (GC/MS) and GC/combustion/isotope ratio MS (GC/C/IRMS) to identify the compounds present and determine their  $\delta^{13}\text{C}$  values, respectively. GC/MS analyses were conducted using a ThermoQuest TraceMS instrument (ThermoQuest, Hemel Hempstead). The derivatized sample was injected (1.0 µl) onto a column (CPSil-5CB, 50 m × 0.32 mm × 0.12 µm, Agilent J&W), as solutions in ethyl acetate, *via* a programmable temperature vaporising (PTV) injector; ramping from 70°C to 300°C at a rate of 14°C s<sup>-1</sup> and maintaining this temperature for the duration of the oven programme (see below). Helium was used as the carrier gas. The GC oven temperature was held at 70°C for 2

min, following injection, then programmed to 200°C at a rate of 10°C min<sup>-1</sup> then to 300°C at a rate of 3°C min<sup>-1</sup> with a final hold time of 20 min. The ion source was maintained at 200°C and the transfer line at 300°C. The emission current was set to 150 A and the electron energy to 70 eV. The analyser was set to scan  $m/z$  50–650 with a duty cycle time of 0.6 s. GC/MS peak assignments were made by comparison with known mass spectra. A ThermoFinnigan Delta<sup>Plus</sup> XP instrument (Thermo Electron Corporation) was used to determine the  $\delta^{13}\text{C}$  values of the compounds identified in the lamp deposit TLE. The MS (EI, 100 eV, three Faraday cup collectors  $m/z$  28, 29 and 30) was interfaced to a Thermo Electron Trace 2000 GC *via* a ThermoElectron GC combustion III interface (CuO/NiO/Pt oxidation reactor maintained at 940 °C and Cu reduction reactor maintained at 600 °C). Derivatised TLE was introduced using a PTV injector as above. Helium was used as the carrier gas whilst column and temperature programmes were the same as those used for the GC/MS analyses.

## Discussion of dating discrepancies

All the Kavastu lamp fuel samples were dated at the Oxford Radiocarbon Accelerator Unit (ORAU). Samples were taken at the museum using a clean scalpel and stored in aluminium foil to avoid contamination from plasticizers from packaging. The bulk samples went through the standard sample preparation protocol (Brock *et al.* 2010). However, the total lipid extract (TLE) sample was obtained after solvent extraction at the University of Bristol School of Chemistry laboratory as part of the lipid residue analysis and was essentially combusted and dated at ORAU with no additional preparation.

The AMS date of the TLE gave a result of  $2319 \pm 31$  BP, cal. 430–356 BC (88.4% probability). This predates the earliest occurrence of this type of lamp according to artefact chronology by several centuries. It is also almost a millennium earlier than the two bulk fuel dates and it seems unrealistic to conclude that a passage of ~800–1000 years had passed between the two purported events being dated.

Contamination is sometimes a serious issue in the field of radiocarbon dating and it may be significant in explaining our TLE dating result. Contaminants affect samples in quite different ways, and much depends on the ‘true’ age of the sample and the age of the contaminant. They can be both old and young, and come from the site or from excavation, conservation, storage and from the analysis of the sample in the laboratory (Lanting & van der Plicht 1998; Fischer



& Heinemeier 2003; van der Plicht *et al.* 2014; Gillespie & Hedges 1984; Stott *et al.* 2001; Yates *et al.* 2014; 2015a-b). It is noteworthy that in the case of microsamples (our TLE weight was 1.31 mg) the issues of contamination can be very critical, affecting the measurements significantly, and lipids in general tend to be more susceptible to contamination (Yates *et al.* 2015a).

For relatively recent material such as the Kavastu lamp fuel, old carbon contaminants are much more significant in causing aberrant determinations compared with modern carbon contaminants. A 10% contribution of old carbon will make an AMS sample ~800 years too old, regardless of its age. For near modern samples, on the other hand, a much greater proportion of modern carbon is required to shift the age significantly. Thus a more likely explanation for the discrepancy in our bulk and TLE dating results is the introduction of old carbon to the TLE sample.

Exactly how this has happened is difficult to pin down. In the lipid residue analysis we only see the compounds that are amenable to GC fitting into the analytical window previously defined. However, the TLE also contains compounds that have a higher molecular weight and/or are much more polar, and indeed, may be older. The AMS date for a TLE is therefore not truly comparable to a few fatty acids, but probably also includes substances unseen and unknown to us. The latter can easily contain old carbon resources affecting the dating results of the TLE. For a true comparison one would need to date the fatty acid fraction or specific fatty acids which we cannot, as yet, separate for the AMS dating. In addition, unremoved solvent from the TLE might also play a role in producing ages that are older than they should be.

Although the AMS results of the two bulk samples do not overlap entirely, they are very close, falling into the first half of the first millennium AD and as such do not contradict the typo-chronological context of the lamp. On the contrary, the dating of the TLE precedes the occurrence of this lamp type by several centuries. Therefore we consider the TLE age erroneous for dating the usage of lamp for illumination purposes and favour the two bulk determinations —  $1699 \pm 33$  BP and  $1561 \pm 25$  BP — as more likely accurate providing a *terminus post quem* for the deposition of the object.

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